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Gravitational waveforms from the inspiral of compact binaries in the Brans-Dicke theory in an expanding Universe

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In modified gravity theories, such as the Brans-Dicke theory, the background evolution of the Universe and the perturbation around it are different from that in general relativity. Therefore, the gravitational waveforms used to study standard sirens in these theories should be modified. The modifications of the waveforms can be classified into two categories: wave generation effects and wave propagation effects. Hitherto, the waveforms used to study standard sirens in the modified gravity theories incorporate only the wave propagation effects and ignore the wave generation effects; while the waveforms focusing on the wave generation effects, such as the post-Newtonian waveforms, do not incorporate the wave propagation effects and cannot be directly applied to the sources with non-negligible redshifts in the study of standard sirens. In this work, we construct the consistent waveforms for standard sirens in the Brans-Dicke theory. The wave generation effects include the emission of the scalar breathing polarization h_b and the corrections to the tensor polarizations h_+ and $h_\times$; the wave propagation effect is the modification of the luminosity distance for the gravitational waveforms. Using the consistent waveforms, we analyze the parameter estimation biases due to the ignorance of the wave generation effects. Considering the observations by the Einstein Telescope, we find that the ratio of the theoretical bias to the statistical error of the redshifted chirp mass is two orders of magnitude larger than that of the source distance. For black hole-neutron star binary systems like GW191219, the theoretical bias of the redshifted chirp mass can be several times larger than the statistical error.

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